STUDIES OF MAGNITUDES IN STAR CLUSTERS. VI. THE RELATION OF BLUE STARS AND VARIABLES TO GALACTIC PLANES

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The possibility of the invariable presence of axes of symmetry in globular clusters is attested by the results given in a recent communication by Mr. Pease and the present writer.[1] The observed elliptical distribution of stars may denote a prolate spheroidal form; or, as appears more probable, it may signify the projection of a discoidal figure, in which case the axis of symmetry represents the lines of intersection with the celestial sphere of the central plane of a system analogous in form to our own Galaxy. In any case the phenomenon of symmetrical elongation may be highly significant in problems of stellar dynamics, and as such is deserving of further study.

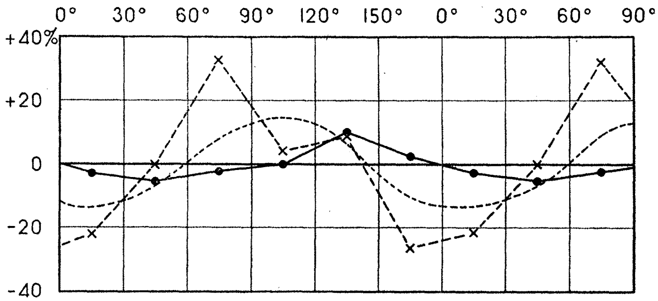
One method of investigation is the study in globular clusters of the distribution of those objects which show a peculiar arrangement in our galactic system with respect to the plane of the Milky Way. It does not follow, of course, that they should also show condensation along a symmetrical plane in all large stellar systems, but it will be of interest and of much importance to know whether or not they do.

Stars of spectral class B and the longer-period Cepheid variables are two types of objects which in the local system show a strong galactic preference. Data bearing on both of these are available for Messier 13—the only globular cluster for which a detailed study of magnitudes and colors has been made.[2] Earlier discussions of the distribution with respect to the center of the brightest thousand stars of Messier 13 failed to show a definite tendency toward symmetrical elongation,[3] but, from an investigation of some 30,000 faint stars in this system, we now know with considerable accuracy the position of its axis of symmetry. With the orientation of the density ellipse as a starting point, the bright stars have been rediscussed from the standpoint of color index. The method of treatment is sufficiently indicated in the earlier communication relative to axes of symmetry.

The smooth dotted curve in figure 1 is based upon the count of 10,000 stars between the seventeenth and nineteenth magnitudes, and is inserted merely to show the true position of the axis, and, by means of the amplitude of the curve, to indicate the degree of the ellipticity. The ordinates are the percentage deviations of the number of stars in each 30° sector from the mean number for all sectors; the abscissae are

angles of direction from the center (expressed as position angles), the data for opposite sectors being combined into means. Compared with this dotted curve it is apparent that the thousand brightest stars, represented by the full line, show little trace of the elliptical distribution.

Of this group of bright stars, 130 have negative color indices. They correspond, at least approximately, to the B-class stars in our galactic system, which show marked galactic concentration. Their distribution is plotted in figure 1 as a broken line. Though the accidental variations are influential, because of the relatively small numbers concerned, the elongation is definitely shown and the degree of concentration appears to be about double that for the faint stars of all color classes.



Full line, brightest thousand stars; broken line with crosses, blue stars; dotted line, all stars between magnitudes 17 and 19. Ordinates, percentage deviation from the mean; abscissae, angle of direction from the center.

There are seven variable stars in the Hercules cluster. Four of them, including the two that are known certainly to be Cepheid variables, are in the sectors that contain the axis of symmetry, and one is in an adjoining sector. As some allowance for the inclination of the supposed plane to the line of sight must be made, this proportion is as much as could be expected, even if all these are Cepheids and in their distribution a strict comparability to the condition in our system is required.

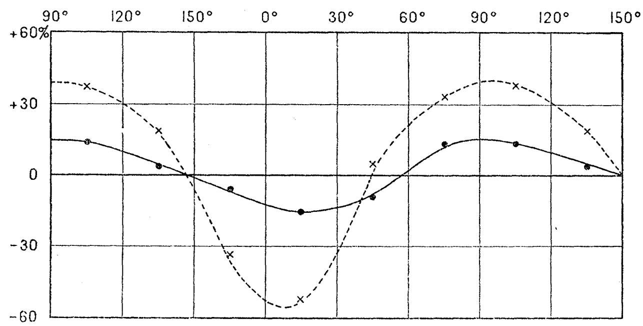
The elliptical form of ω Centauri, the largest and brightest globular cluster in the sky, is immediately evident upon photographs that show several thousands of its stars. The apparent elongation was mentioned by Bailey in discussing the variable stars,[4] but was not considered in his discussion of the distribution.[5] That the star counts, as published by Bailey, verify the appearance of the photographs and show a distinctly elliptical symmetry, has been noted in earlier papers.[6]

The data upon which this conclusion was based are now given in the table, the thousand stars nearer the center than 3′ being excluded because of the difficulty and consequent uncertainty in counting and arranging the data in sectors. The successive lines of the table show that

THE DISTRIBUTION OF 5000 STARS IN ω CENTAURI

WIDTH OF RING	SECTORS												MEAN
	15°	45°	75°	105°	135°	165°	195°	225°	255°	285°	315°	345°	
3′ to 6′........	148	129	151	182	165	159	164	173	203	182	198	163	168
6 to 9........	84	89	151	142	139	113	105	119	153	163	125	117	125
9 to 12........	66	81	96	74	64	79	64	68	88	97	74	68	77
12 to 15........	44	54	61	61	57	57	40	59	57	59	51	45	54
3 to 9........	232	218	302	324	304	272	269	292	356	345	323	280	293
9 to 15........	110	135	157	135	121	136	104	127	145	156	125	113	130
3 to 15........	342	353	459	459	425	408	373	419	501	501	448	393	423
Variables..............	8	6	17	12	9	5	2	16	11	17	16	9	11

the elliptical distribution is present at all distances from the center. The irregularities and other evidence of the lack of exact symmetry in this cluster, as well as in others, probably represent actual conditions; their significance may be much the same as that of the open star groups and the breaks in the Milky Way in the symmetry of our own galactic system.



The full line shows the distribution of all stars, the minimum corresponding to the direction of the cluster's galactic pole. The dotted line shows the distribution of variables. Ordinates, percentage deviation of the number of stars in each sector from the mean for all sectors; abscissae, angle of direction from the center, expressed as position angle.

There are 128 variables (nearly all short-period Cepheids) in ω Centauri. Their distribution is given in the last line of the table, and their relation to the axis of symmetry is shown in figure 2. In the diagram, numbers for opposite sectors are combined and the percentage deviations from the means are plotted together with a similar curve for the five thousand stars of all kinds outside the central area. The preference for the sectors that lie along the axis of symmetry is very conspicuous, the relative amplitudes of the two curves showing that these short-period variables are three times as condensed toward the supposed plane of symmetry as the stars in general. A correction for superposed stars increases the general ellipticity by about one-tenth of its amount.

The hundred or so brightest short-period Cepheids (cluster-type variables) in the galactic system do not show a marked concentration to the plane of the Milky Way. This result is not conclusive, however. There are hundreds of known variable stars in low galactic latitudes whose periods and variations are not yet recognized. If, as may well be the case, these prove to be short-period Cepheids which appear faint because of distance, though intrinsically fairly luminous, our ideas relative to their galactic concentration will need modification. In fact, we probably have much more complete information about the Cepheid variables in ω Centauri than in our own system, and for the former the information is also homogeneous.

Summary. (1) When based on photographs with exposures long enough to show ten or twenty thousand stars, the study of stellar distribution in the so-called globular clusters reveals an underlying elliptical symmetry that may be universally present. (2) The 130 brightest stars of color class B in Messier 13 show a distinct preference for the sectors containing the axis of symmetry, which was previously found for faint stars but is not shown by the thousand brightest objects of all color classes. (3) The Cepheid variables in Messier 13 also aline themselves along this axis. (4) The southern cluster ω Centauri shows a conspicuous elliptical distribution, even when only the brightest 5000 stars are examined. (5) The 128 short-period variables in this cluster show a much higher concentration toward the axis of symmetry than do the other stars. (6) Because of the analogous condition in our Galaxy, the peculiar concentration of blue stars and variables strongly supports the hypothesis that these axes of symmetry in reality represent the projections of more or less oblate systems of stars; and it indicates that in this flattened form, which appears not only as a characteristic of various kinds of nebulae, but also of the solar system, of the whole galactic system, and now even of globular clusters, we have a property that is general and fundamental in the dynamics of stellar groups.

[1] Pease, F. G., and Shapley, H., these PROCEEDINGS, **3**, 1917, (96–101).

[2] Shapley, H., *Mt. Wilson Contrib.* No. 116, 1915, (1–92).

[3] *Ibid.*, page 87.

[4] Bailey, S. I., *Ann. Obs. Harvard Coll., Cambridge*, **38**, 1902, (1–252), page 5.

[5] Bailey, S. I., *Astr. and Astroph., Northfield, Minn.*, **12**, 1893, (689–692).

[6] Shapley, H., *loc. cit.*, and *Observatory, London*, **39**, 1916, (452–456), page 456.